

**CLAIMS:**

1. A multilayer pipe comprising:
  - (a) a first thermoplastic tubular structure comprising (i) a polyolefin material selected from the group consisting of polypropylene, copolymers of polypropylene with other olefins, polyethylene, and copolymers of ethylene with other olefins and (ii) a functionalized polymer, an acid terpolymer, or an ethylene acid copolymer;
  - (b) a second thermoplastic tubular structure comprising (i) a polyolefin material selected from the group consisting of polypropylene, copolymers of polypropylene with other olefins, polyethylene, and copolymers of ethylene with other olefins and (ii) a functionalized polymer, an acid terpolymer, or an ethylene acid copolymer;
  - (c) the second thermoplastic tubular covering the first thermoplastic tubular structure; and
  - (d) a barrier layer disposed between the first thermoplastic tubular structure and the second thermoplastic tubular structure.
2. The multilayer pipe of Claim 1, wherein the functionalized polymer is maleic anhydride.
3. The multilayer pipe of Claim 1 wherein the barrier layer has a carbon dioxide permeability of less than  $0.50 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
4. The multilayer pipe of Claim 1 wherein the barrier layer has a carbon dioxide permeability of less than  $0.10 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
5. The multilayer pipe of Claim 1 wherein the barrier layer has a carbon dioxide permeability of less than  $0.01 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
6. The multilayer pipe of Claim 1 wherein the first thermoplastic tubular structure and the second thermoplastic tubular structure each further

comprise a hydrocarbon resin, the hydrocarbon resin having a melt flow rate of between about 10 and 40 g/10 min. at 230° C at 2160 g and a density of between about 0.90 and 1.10 g/cm<sup>3</sup>.

7. The multilayer pipe of Claim 1 wherein the first thermoplastic tubular structure, second thermoplastic tubular structure, and the barrier layer are coextruded.
8. The multilayer pipe of Claim 1 wherein the barrier layer comprises an ethylene vinyl alcohol copolymer.
9. The multilayer pipe of Claim 6 wherein the barrier layer comprises an ethylene vinyl alcohol copolymer.
10. The multilayer pipe of Claim 1 wherein the barrier layer has a thickness of at least 13  $\mu\text{m}$  and no more than 250  $\mu\text{m}$ .
11. The multilayer pipe of Claim 1 wherein the barrier layer has a thickness of at least 13  $\mu\text{m}$  and no more than 60  $\mu\text{m}$ .
12. The multilayer pipe of Claim 8 wherein the first thermoplastic tubular structure, second thermoplastic tubular structure, and the barrier layer are coextruded.
13. The multilayer pipe of Claim 1 wherein the barrier layer comprises one or more of the following: polyamide; nylon; extrudable polyvinylidene chloride; poly(vinyl chloride) (PVC); methyl methacrylate-styrene copolymers (70:30 weight percent, respectively) grafted onto a diene elastomer; amorphous polyamides and crystalline polyamides (nylon-6 and nylon-66); crystalline polyesters such as polyethylene terephthalate (PET); poly(ethylene 2,6-naphthalene dicarboxylate) (PEN); polyurethane; polycarbonate (PC); polyphenylene oxide (PPO); polyphenylene oxide/polystyrene blends; polystyrene; polyetherimide; polyalkyl methacrylate; high nitrile polymer; high acrylonitrile-styrene co- and

terpolymers; high acrylonitrile-indene co- and terpolymers; homo-, co- or terpolymers high in methacrylonitrile content; all common homo-, co-, or terpolymers based on vinylidene dichloride (PVDC); and metalized oriented polypropylene film.

14. The multilayer pipe of Claim 12 wherein the functionalized polymer is maleic anhydride.
15. A multilayer pipe comprising:
  - (a) a first thermoplastic tubular structure having a thickness of at least 875  $\mu\text{m}$ ;
  - (b) a second thermoplastic tubular structure having a thickness of at least 875  $\mu\text{m}$  covering the first thermoplastic tubular structure; and
  - (c) a barrier layer having a thickness of at least 13  $\mu\text{m}$  disposed between the first thermoplastic tubular structure and the second thermoplastic tubular structure.
16. The multilayer pipe of Claim 15 wherein the first thermoplastic tubular structure and the second thermoplastic tubular structure each comprise a polyolefin material selected from the group consisting of polypropylene, copolymers of polypropylene with other olefins, polyethylene, and copolymers of ethylene with other olefins.
17. The multilayer pipe of Claim 16 wherein the barrier layer has a carbon dioxide permeability of less than  $0.50 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
18. The multilayer pipe of Claim 16 wherein the barrier layer has a carbon dioxide permeability of less than  $0.10 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
19. The multilayer pipe of Claim 16 wherein the barrier layer has a carbon dioxide permeability of less than  $0.01 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .

20. The multilayer pipe of Claim 16 wherein the first thermoplastic tubular structure and the second thermoplastic tubular structure each further comprise a functionalized polymer, an acid terpolymer, or an ethylene acid copolymer.
21. The multilayer pipe of Claim 20, wherein the functionalized polymer is maleic anhydride.
22. The multilayer pipe of Claim 16 wherein the first thermoplastic tubular structure and the second thermoplastic tubular structure each further comprise a hydrocarbon resin, the hydrocarbon resin having a melt flow rate of between about 10 and 40 g/10 min. at 230° C at 2160 g and a density of between about 0.90 and 1.10 g/cm<sup>3</sup>.
23. The multilayer pipe of Claim 16 wherein the first thermoplastic tubular structure and the second thermoplastic tubular structure each further comprise a maleic anhydride functionalized polymer and a hydrocarbon resin.
24. The multilayer pipe of Claim 16 wherein the first thermoplastic tubular structure, second thermoplastic tubular structure, and the barrier layer are coextruded.
25. The multilayer pipe of Claim 16 wherein the barrier layer comprises an ethylene vinyl alcohol copolymer.
26. The multilayer pipe of Claim 22 wherein the barrier layer comprises an ethylene vinyl alcohol copolymer.
27. The multilayer pipe of Claim 25 wherein the first thermoplastic tubular structure, second thermoplastic tubular structure, and the barrier layer are coextruded.
28. The multilayer pipe of Claim 15 wherein the barrier layer comprises one or more of the following: polyamide; nylon; extrudable polyvinylidene

chloride; poly(vinyl chloride) (PVC); methyl methacrylate-styrene copolymers (70:30 weight percent, respectively) grafted onto a diene elastomer; amorphous polyamides and crystalline polyamides (nylon-6 and nylon-66); crystalline polyesters such as polyethylene terephthalate (PET); poly(ethylene 2,6-naphthalene dicarboxylate) (PEN); polyurethane; polycarbonate (PC); polyphenylene oxide (PPO); polyphenylene oxide/polystyrene blends; polystyrene; polyetherimide; polyalkyl methacrylate; high nitrile polymer; high acrylonitrile-styrene co- and terpolymers; high acrylonitrile-indene co- and terpolymers; homo-, co- or terpolymers high in methacrylonitrile content; all common homo-, co-, or terpolymers based on vinylidene dichloride (PVDC); and a metalized oriented polypropylene film.

29. The multilayer pipe of Claim 15 wherein the first tubular structure is chemically or mechanically secured to a surface of the barrier layer and the second tubular structure is chemically or mechanically secured to an opposing surface of the barrier layer.
30. The multilayer pipe of Claim 15 wherein the barrier layer has a thickness of no more than 250  $\mu\text{m}$ .
31. The multilayer pipe of Claim 15 wherein the barrier layer has a thickness of no more than 60  $\mu\text{m}$ .
32. A reinforced multilayer pipe comprising:
  - (a) a first thermoplastic tubular structure;
  - (b) a second thermoplastic tubular structure covering the first thermoplastic tubular structure;
  - (c) a reinforcing structure covering the second thermoplastic tubular structure; and

- (d) a barrier layer disposed between the first thermoplastic tubular structure and the second thermoplastic tubular structure.
33. The reinforced multilayer pipe of Claim 32 wherein the first thermoplastic tubular structure, the barrier layer, and the second thermoplastic tubular structure are coextruded.
34. The reinforced multilayer pipe of Claim 32 wherein the barrier layer comprises one or more of the following: polyamide; nylon; extrudable polyvinylidene chloride; poly(vinyl chloride) (PVC); methyl methacrylate-styrene copolymers (70:30 weight percent, respectively) grafted onto a diene elastomer; amorphous polyamides and crystalline polyamides (nylon-6 and nylon-66); crystalline polyesters such as polyethylene terephthalate (PET); poly(ethylene 2,6-naphthalene dicarboxylate) (PEN); polyurethane; polycarbonate (PC); polyphenylene oxide (PPO); polyphenylene oxide/polystyrene blends; polystyrene; polyetherimide; polyalkyl methacrylate; high nitrile polymer; high acrylonitrile-styrene co- and terpolymers; high acrylonitrile-indene co- and terpolymers; homo-, co- or terpolymers high in methacrylonitrile content; all common homo-, co-, or terpolymers based on vinylidene dichloride (PVDC); and a metalized oriented polypropylene film.
35. The reinforced multilayer pipe of Claim 32 wherein the barrier layer has a carbon dioxide permeability of less than  $0.10 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
36. The reinforced multilayer pipe of Claim 32 wherein the barrier layer has a carbon dioxide permeability of less than  $0.01 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
37. The reinforced multilayer pipe of Claim 32 wherein the reinforcement structure is a steel tubular.
38. The reinforced multilayer pipe of Claim 32 wherein the reinforcing structure is a drill well tubular.

39. The reinforced multilayer pipe of Claim 32 wherein the reinforcing structure is a production tubing tubular.
40. The reinforced multilayer pipe of Claim 32 wherein the reinforcing structure is a production casing tubular.
41. The reinforced multilayer pipe of Claim 32 wherein the reinforcing structure is a sewer line tubular.
42. The reinforced multilayer pipe of Claim 32 wherein the barrier layer has a thickness of at least 13  $\mu\text{m}$  and no more than 250  $\mu\text{m}$ .
43. The reinforced multilayer pipe of Claim 32 wherein the barrier layer has a thickness of at least 13  $\mu\text{m}$  and no more than 60  $\mu\text{m}$ .
44. The multilayer pipe of Claim 32 wherein the barrier layer comprises an ethylene vinyl alcohol copolymer.
45. A well tubing joint comprising:
  - (a) a first thermoplastic tubular structure;
  - (b) a second thermoplastic tubular structure covering the first thermoplastic tubular structure;
  - (c) a rigid tubular section covering the second thermoplastic tubular structure; and
  - (d) a barrier layer disposed between the first thermoplastic tubular structure and the second thermoplastic tubular structure.
46. The well tubing joint of Claim 45 wherein the first and second thermoplastic layer comprise a polyolefin material selected from the group consisting of polypropylene, copolymers of polypropylene with other olefins, polyethylene, and copolymers of ethylene with other olefins.

47. The well tubing joint of Claim 45 wherein the first and second thermoplastic layers further comprise a functionalized polymer, an acid terpolymer, or an ethylene acid copolymer.
48. The well tubing joint of Claim 47, wherein the functionalized polymer is maleic anhydride.
49. The well tubing joint of Claim 45 wherein the rigid tubular section comprises a steel tubular.
50. The well tubing joint of Claim 45 wherein the first thermoplastic tubular structure, the barrier layer, and the second thermoplastic tubular structure are coextruded.
51. The well tubing joint of Claim 45 wherein the barrier layer has a carbon dioxide permeability of less than  $0.50 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
52. The well tubing joint of Claim 45 wherein the barrier layer has a carbon dioxide permeability of less than  $0.10 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
53. The well tubing joint of Claim 45 wherein the barrier layer has a carbon dioxide permeability of less than  $0.01 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
54. The well tubing joint of Claim 45 wherein the barrier layer has a thickness of at least  $13 \text{ }\mu\text{m}$  and no more than  $250 \text{ }\mu\text{m}$ .
55. The well tubing joint of Claim 45 wherein the barrier layer has a thickness of at least  $13 \text{ }\mu\text{m}$  and no more than  $60 \text{ }\mu\text{m}$ .
56. A process for the manufacture of a multilayer pipe, the process comprising:
  - (a) extruding a first thermoplastic tubular structure comprising (i) a polyolefin material selected from the group consisting of polypropylene, copolymers of polypropylene with other olefins, polyethylene, and



copolymers of ethylene with other olefins and (ii) a functionalized polymer, an acid terpolymer, or an ethylene acid copolymer;

(b) coextruding with the first thermoplastic tubular structure, a second thermoplastic tubular structure comprising (i) a polyolefin material selected from the group consisting of polypropylene, copolymers of polypropylene with other olefins, polyethylene, and copolymers of ethylene with other olefins and (ii) a functionalized polymer, an acid terpolymer, or an ethylene acid copolymer;

(d) coextruding with the first thermoplastic tubular structure and the second thermoplastic tubular, a barrier layer having a minimum thickness of at least 13  $\mu\text{m}$  and disposed between the first thermoplastic tubular structure and the second thermoplastic tubular structure.

57. The process of Claim 56, wherein the functionalized polymer is maleic anhydride.
58. The process of Claim 56 wherein the coextruded barrier layer has a carbon dioxide permeability of less than  $0.50 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
59. The process of Claim 56 wherein the coextruded barrier layer has a carbon dioxide permeability of less than  $0.1 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
60. The process of Claim 56 wherein the coextruded barrier layer has a carbon dioxide permeability of less than  $0.01 \text{ cm}^3/100 \text{ cm}^2/\text{day}/100 \text{ kPa}$ .
61. The process of Claim 56 wherein the barrier layer comprises ethylene vinyl alcohol.
62. The process of Claim 56 further comprising placing the multilayered pipe inside a reinforcing structure.
63. The process of Claim 56 wherein the first tubular structure is chemically or mechanically secured to a surface of the barrier layer and the second

tubular structure is chemically or mechanically secured to an opposing surface of the barrier layer.